

SEXUAL INVERSION IN *CORIS JULIS* L. 1758

by

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ABSTRACT. — We have carried out in the laboratory a series of observations on controlled groups of *Coris*, during their reproductive period. Our aim was to study in this protogynous hermaphroditic wrasse behavioural social traits which may trigger sexual inversion. In groups of females we always observed a case of sexual inversion on the largest animal. In contrast this never occurred in groups containing a male. In addition we observed that the presence of males in groups of females which have evident morphological characteristics of inversion does not inhibit the complete inversion of some of the females.

RESUME. — Une série d'observations a été faite au laboratoire sur des groupes contrôlés de *Coris*, pendant leur période de reproduction. Le but était l'étude, chez ce Labridae hermaphrodite protogyne, des caractères du comportement social qui pouvaient avoir une influence sur l'inversion sexuelle. Dans les lots de femelles, il a toujours été observé un cas d'inversion sexuelle chez le plus grand individu. Au contraire ceci n'a jamais été observé dans les lots contenant un mâle. De plus, dans les lots de femelles qui présentaient des caractères morphologiques évidents d'inversion, la présence de mâles n'inhibe pas l'inversion complète de certaines femelles.

Key-words : Pisces, Labridae, *Coris jolis*, sex reversal

Reports on colour and sex of one of the most common Mediterranean labrids, *Coris julis*, are contradictory and confused. Because of the remarkable differences in colour between small and large individuals, this labrid was considered as two different species : *Coris giofredi* (Risso, 1810) (*Julis giofredi*), the smaller form with rather dull constant colours, tending to yellow-brown, and *Coris julis* (L., 1758) (*Julis vulgaris*), the more brightly coloured and varied form. At the end of the last century, the different colour patterns were attributed to an effect of a marked sexual dichromatism, and *Coris julis* L. and *Coris giofredi* Risso were considered as a single species (Steindachner, 1860; Vinciguerra, 1883).

Bacci and Razzauti (1957) found that *Coris julis* was subject to spontaneous protogynous sexual inversion, with a short inversion phase, and long, exclusively male or female, phases. Moreover they reported that sexual change, as in most labrids, was accompanied by striking changes of the colour pattern. Most samples of the more coloured phase examined i.e. « *julis* » were males, and most with a more dull colour i.e. « *giofredi* » were females. Moreover, the latter group also contained males with functional testis. These findings were confirmed by Reinboth (1957, 1962).

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Reinboth (1963, 1969) also found that *Coris* is a diandric species with primary and secondary males and that sexual inversion from females to males is clearly correlated with a change in colour pattern (Reinboth, 1970). However, even though individuals with morphological characteristic intermediate between « julis » and « giofredi » colour pattern have gonads in the inversion stage, the correlation between coloration and gonadic state is not always clear (Reinboth, 1975). In fact, some « giofredi » type specimens have a relatively well developed testis, while some specimens with an almost completely « julis » colour pattern have gonads with prevalently ovaric elements.

Hence, the hermaphrodite *Coris julis* has a very extensive sexual variability that may be described as a series of phenotypes: pure or primary males, protogynous hermaphrodites with retarded passage to male phase and, probably, individuals that always retain the female phase.

As yet nothing is known about the mechanisms underlying sexual inversion, however age seems to play a role in triggering the phenomenon as females change sex when they reach a certain size (Choat, 1969; Roede, 1972; Warner, 1975a, b; Charnov and Bull, 1977). Small males are very rarely found in purely monandric populations (species in which all the males derive ontogenetically from females), which show a distinct sexual size distribution. The size at which males first appear in the population is the same as that at which females change sex (Wenner, 1972). Thus, age is not the only factor causing the inversion in diandric species. In population of *Coris julis* primary males are found that are not only smaller than males coming from a regular inversion, but also smaller than females themselves. Furthermore, as yet there is no evidence that females, whatever the species, change sex upon reaching a uniform size.

The aim of this work is to identify factors that determine sexual inversion and to investigate if behaviour influences sexual inversion.

MATERIALS AND METHODS

Samples were purchased weekly, from September 1981 up to August 1982, from the fish market of Pozzuoli (Gulf of Naples).

Morpho-histological date. The external colour pattern, length and weight of each individual was noted, and the gonads were analyzed. Colour patterns were identified as: « giofredi », transitional, and « julis », according to the criteria established by Bacci and Razzauti (1957).

The sexual phase was determined by histological analysis of the gonads. The gonads were dissected, weighed and fixed in Bouin Solution. They were then sectioned at a thickness of 7 microns and the sections were stained with Azan-Mallory's method or Mayer's haemalum and eosin.

Behavioural investigations. Samples of *Coris julis* were caught in the Gulf of Naples and transported to the Zoological Station in buckets equipped with battery-ventilators. They were kept for at least a week in a circular tank, 345 cm in diameter, with circulating sea-water. The animals were anesthetized (150 mg MS222 +

150 mg NaHCO_3 in a litre of sea-water) and were marked with a coloured bead attached near the dorsal fin. The total and standard length, maximum weight of each animal was recorded.

MORPHO-HISTOLOGICAL DATA

Detailed descriptions of colour patterns of *Coris julis* and *Coris giofredi* are given by Cuvier and Valenciennes (1839) and Gourret (1893). We clearly distinguished two different colour patterns which were related to sex. « Giofredi » individuals have a brown or red coloured back and a white abdomen. A wide yellow-gold band is present on each side of the ventral area. A dark or black spot is present on the upper corner of the opercle. The odd fins are yellow or orange, the even fins are transparent or whitish. The tail-fin is often greenish (Fig. 1).

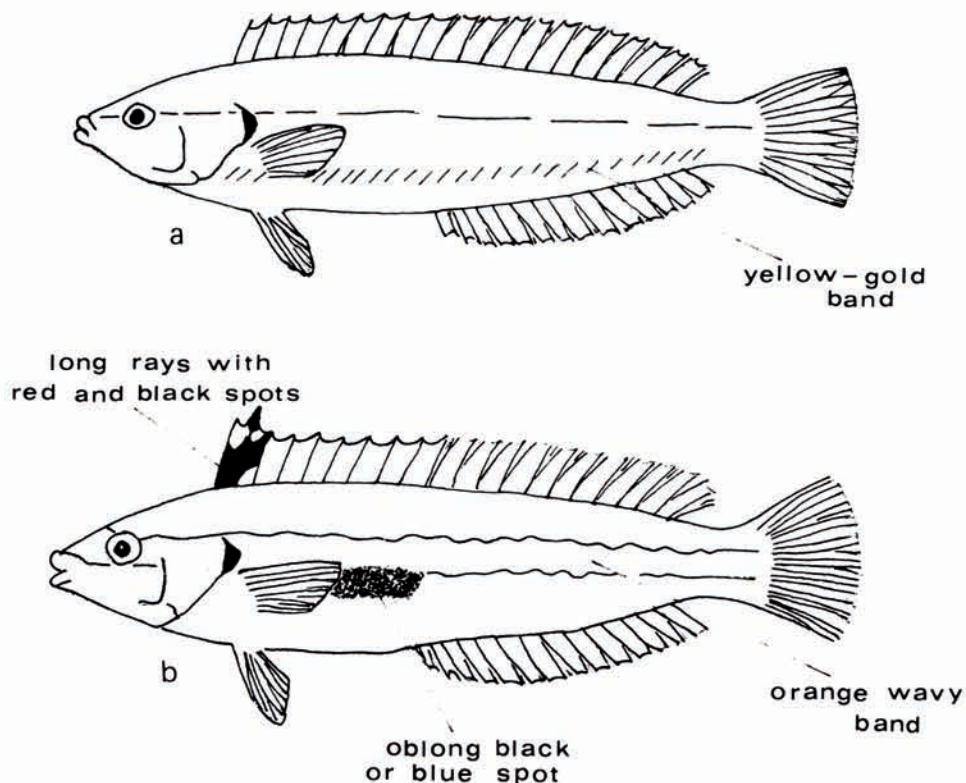
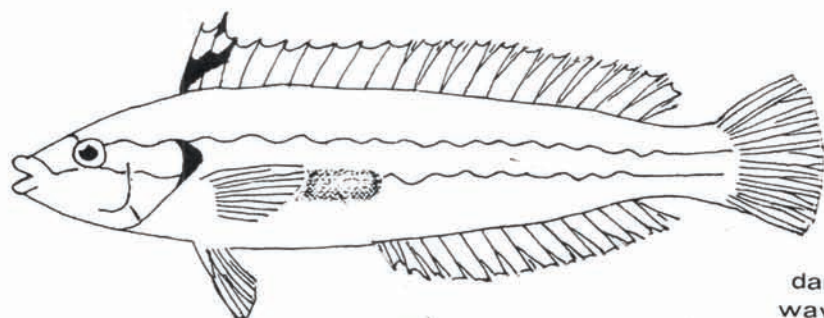


Fig. 1. — « Giofredi » (a) and « julis » (b) colour patterns.

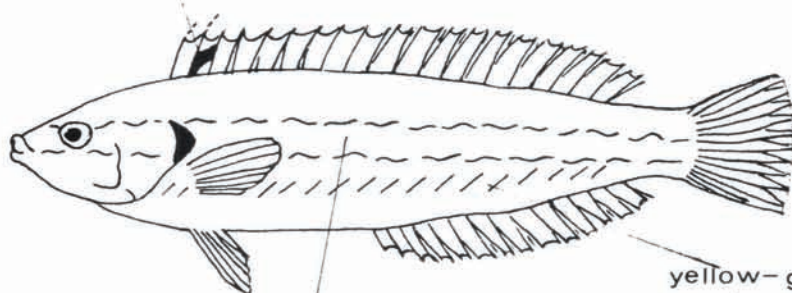
long rays
red and black spots



development of
black pectoral spot

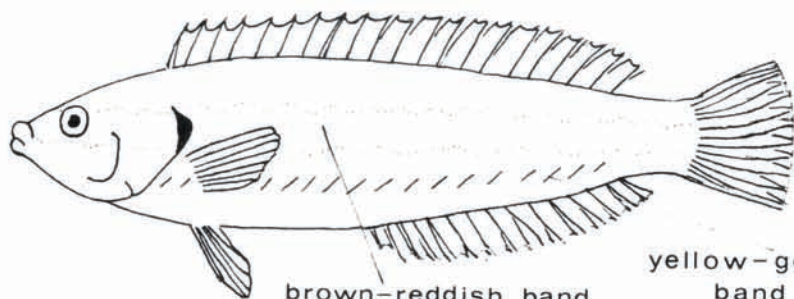
dark orange
wavy band

dark shading
between the first rays



orange wavy band

yellow-gold
band



brown-reddish band
with wavy edges

yellow-gold
band

Fig. 2. - Transitional colour patterns.

« Julis » individuals are much more brightly coloured. They have a green or turquoise back and a white or yellow abdomen. A dark orange wavy band, is present along the sides, often bordered by a thick sky-blue line. Under this band, behind the pectoral fin, there is an oblong, black or blue spot. A small black or blue spot is evident on the upper corner of the opercle. Dorsal and anal fins are yellow or orange, usually bordered by sky-blue; the first three rays of the dorsal fin are longer than the others and show typical red and black spots. The even fins are yellow or transparent. The caudal fin varies in colour (Fig. 1). An analysis of animals kept under observation showed that the passage from a « giofredi » colour pattern to a « julis » colour pattern is marked by the appearance of characters in the following succession (Fig. 2) :

- 1) brown-reddish band with wavy edges in the position that will be successively occupied by the orange longitudinal band;
- 2) a dark shading between the first rays of the dorsal fin;
- 3) slight lengthening of the first three dorsal rays and appearance of black and red spots;
- 4) development of the black pectoral spot and the orange band with complete growth of the dorsal rays and the related spots;
- 5) disappearance of the yellow-gold ventral band

These characters do not always appear in the described order ; hence the different phenotypes which make the study of sexual variability in this species particularly difficult.

We estimated the population structure by an analysis of 258 *Coris*. Figure 3 illustrates the distribution of sex phases and colour patterns for body size, and the colour pattern-sex ratio. Our findings show that:

- There is no correlation between colour pattern and sexual phase. We observed « giofredi » colour pattern individuals (clearly evident in classes 7-10), transitional colour pattern individuals showing each sexual phase, and « julis » colour pattern individuals with functional ovaries;
- It is not possible to establish a lower critical size for the sex-change: in fact, individuals in transitional phase are found in all the length classes from 8 onwards. A critical size (about class 16) might exist for females, as no females were found in the classes between 16 and 22.

This hypothesis is supported by the regression analysis of the correlation between body size and gonadic weight (Fig. 4). We found that :

- A higher critic body size for females exists at about class 16. Females do not present any higher limit of gonadic weight;
- Also the primary males have a higher critical body size, which is about 15.5, while they have no higher limit of gonadic weight;
- Secondary males do not show a higher critical body size, but they have a lower critical body size, which is at about 10.

Moreover, there is a higher limit of gonadic growth at about 0.75 g.

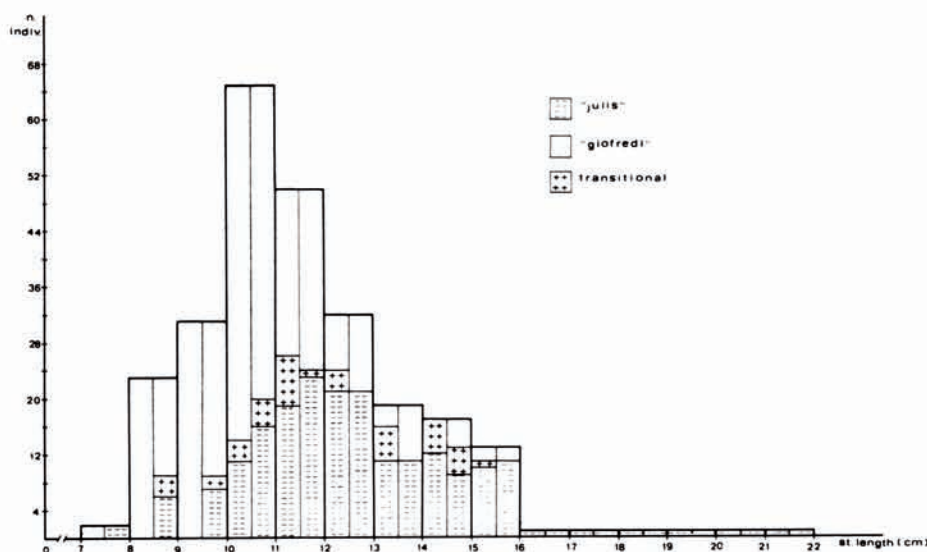


Fig. 3. — Distribution of sex phases and colour pattern for body size, and colour pattern/sex ratio.

BEHAVIOURAL INVESTIGATIONS

Reports of a particular social structure in many families of tropical labrids prompted us to investigate behaviour of the Mediterranean labrid, *Coris julis*.

Preliminary field observations made by us have been recently confirmed by Lejeune (1982). *Coris* with a «giofredi» colour pattern are sedentary, those with a «julis» colour pattern are also territorial. The «meetings» between «julis» individuals often result in agonistic interactions. This territoriality increases during the reproductive period when males are preparing to take over the greater part of the females' area.

Robertson and Choat (1974-1975), in a study on the social system of some proterogynic labroids, recognize two different kind of species: those that live in permanent and territorial groups, a sort of harem species, and those in which there is only a periodic territoriality of large males, during the reproductive period. According to this distinction, *Coris julis* would come within the class of the temporary territorial males. Observations conducted on *Labroides dimidiatus* (Robertson, 1972) and *Thalassoma bifasciatum* (Warner, Robertson and Leigh, 1975) suggest that sexual inversion starts from a sudden alteration in the composition of the social group. According to this hypothesis, in protogynous species, removing a male from a bisexual group, causes an inversion by a female.

We therefore conducted a series of observations on controlled groups of *Coris*, to investigate whether inversion in this species, as in some of the non Mediterranean labrids, is a phenomenon bound to a social behaviour (Fig. 5). The animals were kept in tanks measuring cm 30x40x100 containing continuously circulating sea-water, in a room with uniform temperature without windows. The tanks were sub-

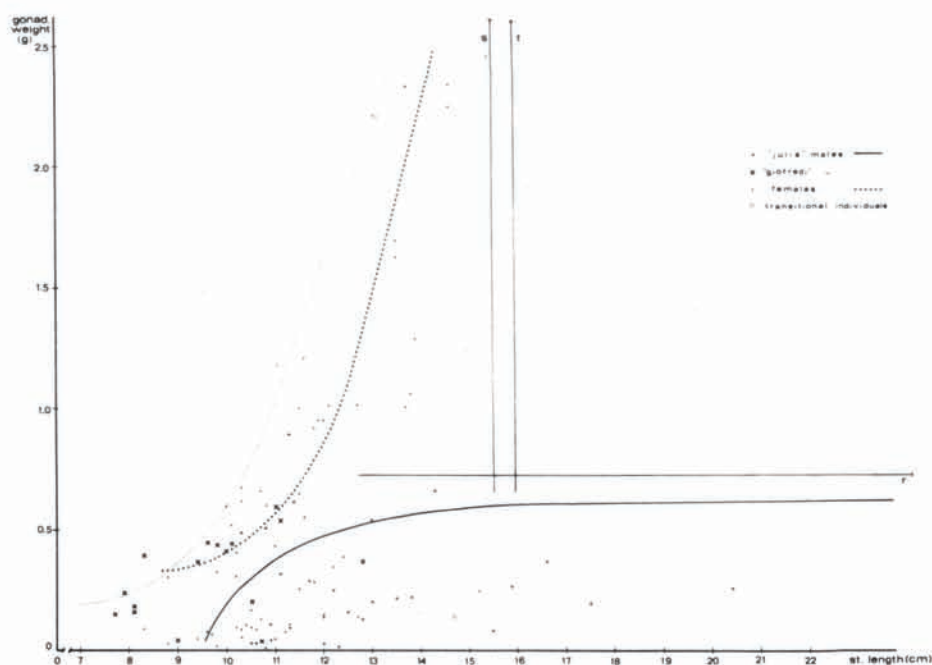


Fig. 4. — Regression analysis of the correlation between body size and gonad weight. Each sample is represented by a point depending on the sexual state. An exponential correlation, represented by an hyperbolic branch, resulted for the two variables.

jected to a twelve-hours cycle of light and dark; the tanks contained sand, the bottom preferred by *Coris*. The animals were fed once a day with sea-urchin gonads, mussels, crabs, etc.

To investigate whether the lack of a male causes the sexual inversion of a female, we placed two groups, group 1 consisting of six females, and group 2 (control) consisting of six females and two males, in two adjacent tanks. The animals had been previously acclimatized and marked (for easy recognition), and the standard length, weight and colour pattern characteristics were noted. The experiment, repeated four times (A-B-C-D) was conducted at the moment of the reproductive period, when the effects of intraspecific interactions are greatest. Each experiment lasted about twenty days. At the end of the 10th day a preliminary observation was made. After about 20 days the animals were killed and their gonads were dissected for histological examination.

A case of prompt sexual inversion always occurred in the tank containing only females, while sexual inversion never took place in the tank containing females and males. We observed that inversion always occurred in the larger females of the group (see Table II). Females are either more subject to inversion at a certain body size (Fig. 4), or inversion is due to the fact that they must substitute a territorial male, which is usually large. Table III gives the morpho-histological characteristics of individuals that changed sex during the four experiments. Our results indicate

tank	initial observation			final observation (after 20 days)		
	date	group 1	group 2 (control)	date	group 1	group 2
A	5/5/82	♀♀ ♀♀ ♀♀	♀♀ ♀♀ ♀♀♂♂	25/5/82	♀♀ ♀♀ ♀ ♂	♀♀ ♀♀ ♀♀♂♂
B	27/5/82	♀♀ ♀♀ ♀♀	♀♀ ♀♀ ♀♀♂♂	17/6/82	♀♀ ♀♀ ♀ ♂	♀♀ ♀♀ ♀♀♂♂
C	19/6/82	♀♀ ♀♀ ♀♀	♀♀ ♀♀ ♀♀♂♂	9/7/82	♀♀ ♀♀ ♀ ♂	♀♀ ♀♀ ♀♀♂♂
D	9/7/82	♀♀ ♀♀ ♀♀	♀♀ ♀♀ ♀♀♂♂	29/7/82	♀♀ ♀♀ ♀ ♂	♀♀ ♀♀ ♀♀♂♂

Fig. 5. – First and last situations of the four experiments.

Table 1. – Frequences of the individuals in female, transitional and male phase, in the different colour patterns, at different length classes.

St.L. Classes	"giofredi"			transitional			"julis"			Tot.
	female	transit.	male	female	transit.	male	female	transit.	male	
7-8	-	-	-	-	-	-	-	-	-	2
8-9	14	3	6	-	-	-	-	-	-	23
9-10	22	2	7	-	-	-	-	-	-	31
10-11	43	3	5	-	1	2	2	-	9	65
11-12	20	-	4	3	-	4	3	1	15	50
12-13	7	-	1	3	-	-	1	-	20	32
13-14	3	-	-	4	1	-	1	1	9	19
14-15	-	-	-	3	1	1	1	3	8	17
15-16	1	-	1	1	-	-	-	-	10	13
16-17	-	-	-	-	-	-	-	-	1	1
17-18	-	-	-	-	-	-	-	-	1	1
18-19	-	-	-	-	-	-	-	-	1	1
19-20	-	-	-	-	-	-	-	-	1	1
20-21	-	-	-	-	-	-	-	-	1	1
21-22	-	-	-	-	-	-	-	-	1	1
Tot.	110	8	26	14	3	7	8	5	77	258

A				B				C				D			
1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
St.L.	Weig.	St.L.	Weig.	St.L.	Weig.	St.L.	Weig.	St.L.	Weig.	St.L.	Weig.	St.L.	Weig.	St.L.	Weig.
12.2	15.2	11.4	11.5	12.1	13.6	12.5	15.2	10.3	13.0	11.0	14.0	10.2	13.0	10.1	11.5
12.3	16.0	11.6	12.6	12.3	14.9	11.4	11.8	9.8	9.5	11.0	16.0	9.5	10.0	9.7	10.1
12.4	14.9	10.7	9.5	11.9	13.0	11.0	9.5	8.8	8.0	7.5	11.5	9.8	11.1	10.1	13.6
12.7	17.5	12.3	13.5	11.6	12.0	11.6	12.7	10.8	16.0	10.1	13.6	9.9	10.0	10.0	12.2
12.1	14.5	10.6	10.0	11.0	9.9	10.6	9.1	10.2	13.0	9.8	11.1	10.3	11.0	10.0	13.0
12.1	13.9	11.0	10.0	12.1	14.0	11.0	11.0	9.5	10.0	11.5	18.0	10.9	13.5	11.0	16.0
		"13.3	"26.0			"17.3	"47.0			"15.5	"46.0			"15.3	"48.0
		"14.2	"34.9			"14.4	"26.8			"13.9	"32.5			"12.7	"20.8

" male

Table II. — Biometrical data of individuals of the four experiments.

	St.Leng.	Weight	Colour patt.	Gonad
A	12.7	17.5	male	testis
B	12.3	14.9	transitional	transitional
C	10.8	16.0	transitional	transitional
D	10.9	13.5	transitional	transitional

Table III. — Morpho-histological characteristics of individuals that changed sex during the four experiments.

that the presence of two males in a social group formed by six females, inhibits sexual inversion.

In other behavioural investigations we found that in a group of six females with only one male there was the prompt inversion of one of the females. Moreover, the presence of two males in a group of six females with clear morphologic characters of the onset of inversion, inhibits the complete inversion of only some of them. It is probable that in the first case another male was required to control the area. The second case could indicate that the inversion mechanism, once started, is no longer affected by social controls.

DISCUSSION

From Table I and Fig. 3 it can be seen that the colour variation (in individuals subject to sex inversion) does not always follow the gonad differentiation, but may also precede it. This finding is confirmed by Reinboth (1975).

The correlation between standard length and gonad weight (Fig. 4), indicates a relative homogeneity among primary gonads (ovary and testis), and a rather li-

mitted gonadic growth rate compared with body growth rate, for secondary gonads (secondary testis). The different gonadic growth rates between primary and secondary males are related to the differences observed in the two colour phases. The male « julis » engages in pair-reproductions; while the male « giofredi » interferes with pair-reproductions and participates in group-reproductions (Lejeune, 1982). A big testis is a selective advantage for « giofredi » males; « julis » males, on the contrary, do not need a big gonad. Robertson and Choat (1974), and Choat and Robertson (1975) found heavier testis in relation to body weight in initial males of some dichromatic labroids than in terminal males, and concluded that this fact was due to basal differences in the reproductive strategies of the two different males.

No distinct distribution of sexual size can be seen in Fig. 3. There is no lower critical size for males; some males are smaller than the females themselves. The lack of females over a certain size could be due to death or to inversion. There is no critical size for animals in the transitional phase (they are found in every length class, starting from 8). Therefore, inversion is not due to age alone.

Our results suggest that the inversion regulation in this species occurs earlier in groups of only females than in mixed groups. It is likely that the lack of the striking male colour pattern, acts as a visual stimulus to prime in females a neuro-endocrine process in order to balance the group sex ratio.

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